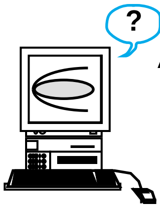

Ask Dr. ALOHA:

ALOHA's "Ladybug Lines"

If you work in emergency planning and response, you probably are familiar with the concept of the "worst case scenario." A worst case is commonly considered to be a situation in which predicted toxic gas concentrations downwind of an accidental chemical release reach or exceed a level of concern at the greatest possible distance from the source. Worst-case weather conditions often are defined as

- "F" atmospheric stability. F is the most stable of the six atmospheric stability classes, which range from A, the least stable, to F, the most stable. F stability usually occurs during clear, calm nights, when atmospheric turbulence is at a minimum.
- a low wind speed. Speeds of 2.2 miles per hour (1.0 meters per second) and 3.4 miles per hour (1.5 meters per second) are often used for emergency planning.

Under these conditions of low wind speed and maximum stability, a cloud of pollutant gas that is neutrally buoyant (about as heavy as air) travels farthest downwind before being diluted to below a level of concern.

When Is Wind Direction Least Predictable?

Another kind of "worst case" also can be of concern to emergency responders. If you're responding to an accidental chemical release, you may need to decide whether or not to evacuate areas downwind of the release, or you may want to establish decontamination and first aid stations at locations you're sure are upwind of the release point. But what if the wind direction changes? You could find yourself deciding to evacuate one area while, as you begin to do so, the wind shifts to blow the chemical cloud in a different direction.

What is the "worst case" for wind direction? Is there a combination of weather conditions under which the wind is most likely to switch to blow a chemical cloud in a different direction than you expected?

The answer is yes. The more unstable the atmosphere, and the slower the wind speed, the more likely is the wind to change direction. The worst case for wind direction is the combination of **"A" stability and a slow wind speed**. You're most likely to see this combination during daylight hours on sunny days, when solar heating generates atmospheric turbulence.

ALOHA's "Ladybug Lines"

ALOHA's footprint plot provides you with a quick, visual estimate of the predictability of the wind direction. An ALOHA footprint includes two main components:

- The **footprint** itself appears as a shaded oval. It represents the region in which ground-level gas concentrations are predicted to exceed your level of concern at some point during the hour after the start of the release, *as long as the wind does not shift direction*.
- To show how much a toxic cloud's position could change if the wind were to shift direction, under the particular weather conditions that you enter, ALOHA draws two dashed lines, one along each side of the footprint. These lines represent the uncertainty (unpredictability) in wind direction. ALOHA predicts that about 95 percent of the time – 19 times out of 20 – the wind will not shift direction enough to blow the pollutant cloud outside of either line.[1] The narrower the zone between the lines, the more predictable is the wind direction and the less likely it is to change substantially. Because the footprint and the two lines together look a little like a ladybug beetle seen from above, ALOHA's developers call the lines the "**ladybug lines**."

  It's important to understand that the ladybug lines represent unpredictability in wind direction only. Other factors, such as wind speed, also greatly influence the size and shape of a dispersing pollutant cloud. ALOHA does not display an estimate for uncertainty in any factor other than wind direction.

On any footprint plot, you'll also see a third component: a curved line running from the end of one ladybug line to the end of the other, and also touching the very tip of the footprint (Figures 1 and 2). In cases when the footprint is no more than 6 miles (10 kilometers) in length, this line represents the farthest downwind extent of the footprint, if the wind were to shift to rotate the footprint toward either ladybug line.

Wind Direction is Less Predictable in an Unstable Atmosphere

Figure 1 shows how the ladybug lines appear for two different release scenarios. In both scenarios, ammonia is released directly into the atmosphere at a rate of 500 pounds (227 kilograms) per minute for 10 minutes, and the wind speed is 3.4

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[1]More exactly, ALOHA uses predicted concentrations that are averaged for about 5 minutes to create a footprint plot, so the ladybug lines bound the area within which the cloud is expected to stay, except for brief excursions beyond either line. ALOHA does not expect 5-minute averaged concentrations to exceed the specified footprint level of concern anywhere outside of the ladybug lines.

miles per hour (1.5 meters per second) at a height of 3 meters. The only difference between the scenarios is in the stability class:

- The uppermost footprint plot shows ALOHA's footprint when the stability class is "F" (very stable).
- The lower plot shows the footprint when the stability class is "A" (very unstable).

Compare the two plots. You'll see that the ladybug lines are much wider—indicating that the wind direction is less predictable—when the atmosphere is least stable ("A" stability):

- Under conditions of F stability, 95 percent of the time, the wind is not expected to shift direction more than about 30 degrees in either direction.
- Under A stability, in contrast, 95 percent of the time, the wind is not expected to shift direction more than 145 degrees in either direction. The lower footprint plot in Figure 1 shows that the wind could shift so substantially that the footprint could rotate almost completely around in either direction.

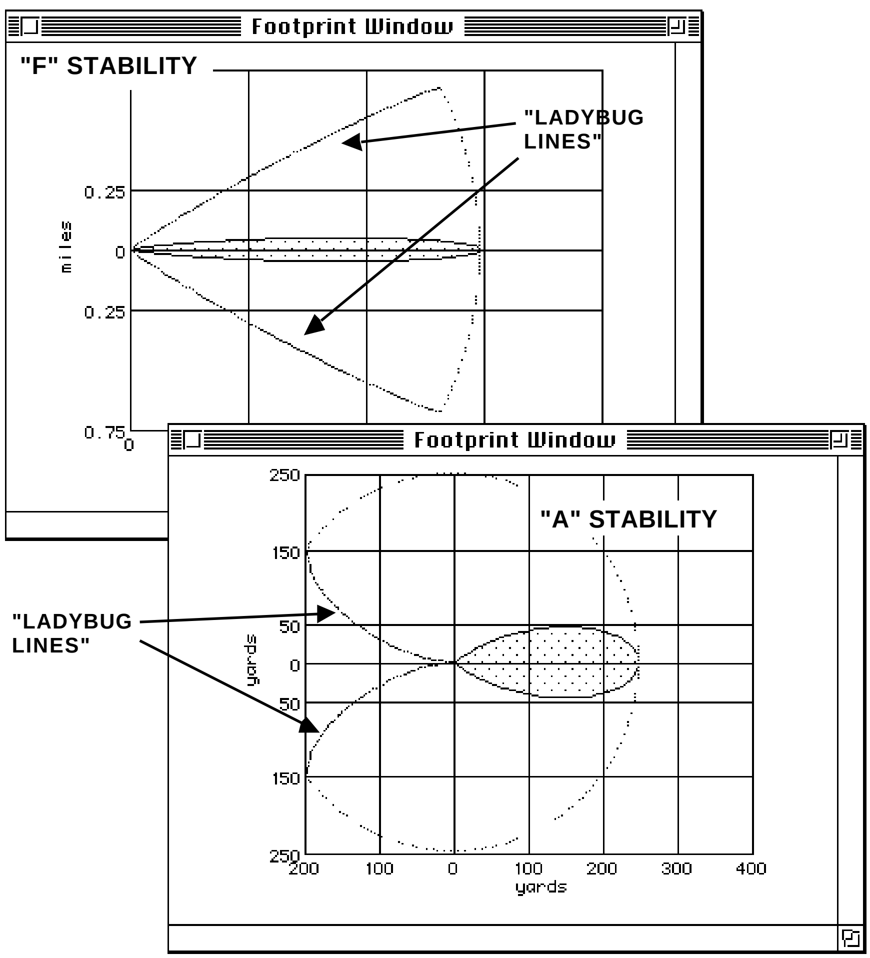

Figure 1. ALOHA's "ladybug lines," representing uncertainty in wind direction, are farthest apart under the least stable atmospheric conditions (stability class A).

Slower Winds Are Less Predictable

No matter how stable the atmosphere, slow winds are more likely to substantially shift direction than faster winds. The slower the wind, the wider apart are ALOHA's ladybug lines. Figure 2 shows how changing wind speed in a scenario, while holding all other conditions constant, changes the position of the lines:

- In the upper plot, when wind speed is only 2 miles per hour (0.9 meters per second) at a height of 3 meters, the wind direction is so uncertain that ALOHA draws a circle, rather than ladybug lines, to show that the wind could switch to blow in any direction.
- At a higher wind speed of 10 miles per hour (4.5 meters per second, at 3 meters height), wind direction is much more predictable, as shown in the lower plot. At this wind speed, 95 percent of the time, the wind is not expected to shift to rotate the footprint more than about 45 degrees in either direction.

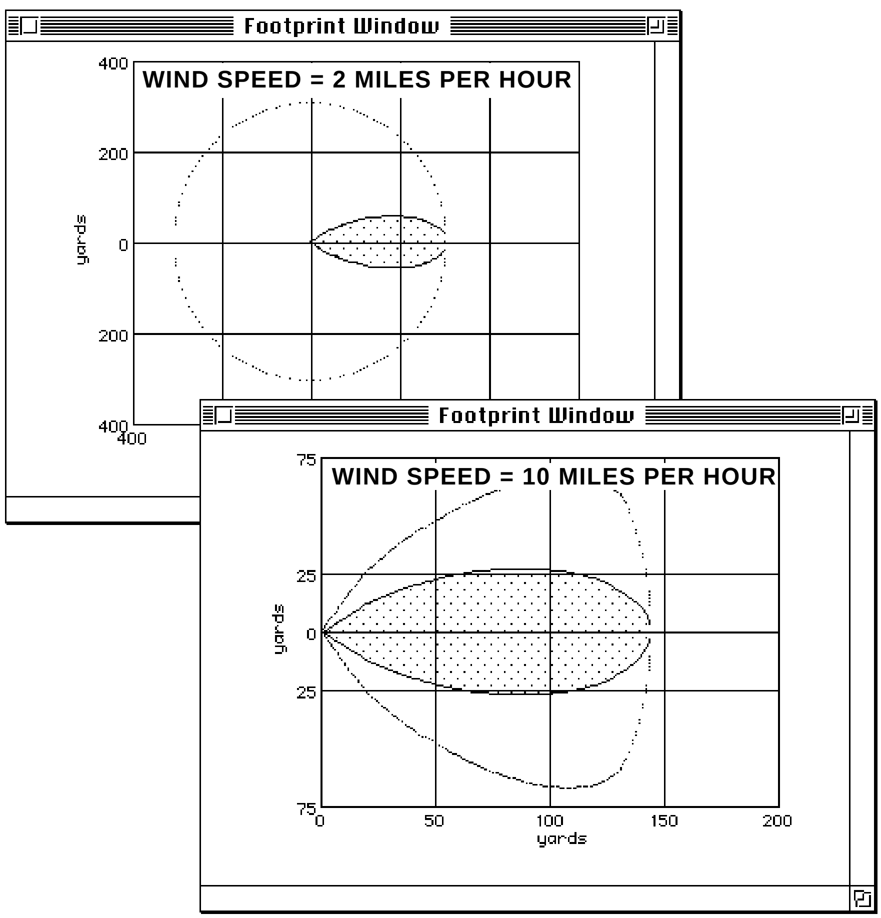

Figure 2. When wind speed is very slow, the wind direction is so uncertain that ALOHA draws a circle, rather than ladybug lines, to show that the wind could switch to blow in any direction (upper footprint plot). At higher wind speeds, wind direction is much more predictable (lower plot).

Consider Wind Direction Uncertainty as Well as Footprint Length

Emergency responders and planners are used to thinking of the type of worst case conditions that maximize the downwind *extent* of the hazard zone, represented by the length of ALOHA's footprint. But during response to an accidental release, remember also to consider how substantially the *position* of the hazard zone could change if the wind shifts direction. Check the "ladybug lines" on your ALOHA footprint when you need this information.

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